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Natural Resource Stewardship and Science

Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

2016 Annual Report

Natural Resource Report NPS/SEAN/NRR—2017/1375

ON THE COVER
Anne Schaefer and Bret Forrester relaying murrelet observations during the 2016 survey
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2016 Annual Report

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Christopher J. Sergeant, William F. Johnson

National Park Service
Southeast Alaska Network, Inventory and Monitoring Program
3100 National Park Road
Juneau, AK 99801

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Executive Summary

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance and spatial distribution of Kittlitz's (KIMU) and marbled murrelets (MAMU) in Glacier Bay National Park and Preserve, an important summer residence for both species. Monitoring program design focuses on KIMU, with secondary consideration of MAMU. The SEAN uses boat-based line transect surveys to estimate species-specific, on-water density and abundance of murrelets, accounting for detection probability and unidentified murrelets.

We surveyed 40 transects totaling 209.4 km from 7-12 July 2016 across the 1,170 km^2 survey area in Glacier Bay proper. We estimated an abundance of 7,025 KIMU (SE = 1,345) and 60,624 MAMU (SE = 12,018). Estimated KIMU abundance was the lowest since monitoring began in 2009 and decreased 35% from 2015, but it was very similar in magnitude to estimates from 2011 and 2013 and is not an obvious cause for concern. Estimated MAMU abundance was nearly the same as the 8-year monitoring average and decreased 28% from 2015. From 2009 to 2016, KIMU abundance estimates have ranged from 7,025 to 16,469 (8-year mean = 10,726), while MAMU have ranged from 28,978 to 84,428 (8-year mean = 60,917).

The SEAN and S. Hoekman (Wild Ginger Consulting) are currently drafting a synthesis report with five major objectives: 1) summarize important results for survey years 2010-2016 with a focus on abundance and spatial distributions of murrelet populations, 2) review and summarize recent scientific literature relevant to the monitoring protocol and management of murrelets in Glacier Bay, 3) assess if field operations have met performance objectives, 4) assess performance of key sampling and analytic methods, and 5) provide recommendations for monitoring protocol revisions to enhance capacity to meet monitoring objectives and for management of murrelets in GLBA. Pending this synthesis report, our results and experience to-date suggest that key operational components of our monitoring protocol are functioning as intended.

The SEAN Kittlitz's Murrelets Resource Brief is a non-technical summary of recent monitoring program highlights and relevance to park management. It can be viewed and downloaded at:

http://science.nature.nps.gov/im/units/sean/auxrep/KM/KM_resource_brief.pdf

Acknowledgments

We could not accomplish these surveys without the help of motivated and talented volunteers: A. Schaefer and B. Forrester collected the majority of 2016 field observations. This work could not be accomplished without the annual support of SEAN Program Manager M. Bower. R. Sarwas has remained closely engaged with the SEAN and accompanied the survey crew in 2016 to help transition the PC-based NPTransect survey software to iOS-based Park Observer. S. Hoekman continues to provide essential survey design and analytical guidance throughout the entirety of this program. J. Lesh assisted with skippering the *R/V Fog Lark*. The Glacier Bay National Park and Preserve Visitor Information Station oversaw boating logistics. Glacier Bay staff, especially L. Sharman, L. Etherington, A. Banks, T. Bruno, and L. Dusin facilitated our research and travel logistics in the park.

Introduction

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance of Kittlitz's murrelets (*Brachyramphus brevirostris*, hereafter "KIMU") and marbled murrelets (*B. marmoratus*, hereafter "MAMU") in Glacier Bay National Park and Preserve. The program arose from concern over potential global and local population declines (Piatt et al. 2011, USFWS 2013, Kirchhoff et al. 2014) and the hypothesis that KIMU populations respond to fluctuations in components of the Glacier Bay marine and terrestrial ecosystems (Moynahan et al. 2008). As part of its Vital Signs Monitoring Program, the SEAN designated KIMU as a priority natural resource with the specific objectives of monitoring status and trends in abundance and spatial distributions.

The KIMU is a seabird endemic to Alaska and northeastern Russia, with the highest breeding population densities in the northern Gulf of Alaska (Day et al. 1999). KIMU in summer are often associated with tidewater glacier and glacial fjord habitats, but also occur in non-glacially influenced areas (Day et al. 1999, Arimitsu et al. 2011, Kissling et al. 2011, Madison et al. 2011). KIMU often forage in proximity to glacier outflows (Day and Nigro 2000, Kuletz et al. 2003) and nest in recently de-glaciated areas with sparse vegetation (Day 1995, Kissling et al. 2015). As a summer resident, open-water, pursuit forager, fluctuations in KIMU populations are likely to be closely linked to variation in marine and terrestrial ecosystems (Moynahan et al. 2008).

SEAN monitoring focuses on estimating early July population abundance and trend primarily for KIMU and secondarily for MAMU. Overall sampling effort is allocated to increase the precision of KIMU abundance estimates (See *Survey Design* section in Methods). Several challenges inherent to Glacier Bay and its murrelet populations complicate estimating murrelet abundance: difficulty distinguishing between the two species, incomplete detection of murrelets along transects, large spatial and temporal variation in populations, and convoluted topography that complicates survey transect placement. The 2009 and 2010 annual KIMU reports, in conjunction with the SEAN's long-term monitoring protocol (Hoekman et al. 2013) fully describe monitoring methods developed to address these challenges.

These annual reports are designed to efficiently deliver data in a concise format, focusing on population abundance and spatial distributions. Periodic syntheses at six-year intervals will assess program performance and population trends; the first of these reports is currently in preparation. Our 2016 study objectives were to complete the eighth year of boat-based line transect surveys, estimate population abundance of KIMU and MAMU in Glacier Bay, describe their spatial distribution, and summarize results since 2009.

Methods

This section includes a brief overview of survey design, survey methods, and analytic approach. Full details can be found in the SEAN long-term monitoring protocol (Hoekman et al. 2013); relevant protocol sections are referenced below.

Study area

Glacier Bay is a narrow, glacial fjord located in Southeast Alaska. The study area encompassed 1,170 km^2 of waters north of Icy Strait and excluded some areas designated as non-motorized waters or those that did not allow safe survey vessel passage (Figure 1; Figure 2.1 in Hoekman et al. 2013).

See Chapter 1 of the SEAN long-term monitoring protocol (Hoekman et al. 2013) and Hoekman et al. (2011a) for more detail.

Survey design

We employed a generalized random tessellation stratified sampling design (GRTS; Stevens and Olsen 2004) to minimize deleterious effects of large spatial variation in murrelet abundance (Drew et al. 2008, Hoekman et al. 2011a,b) by providing a random, spatially-balanced sample. We allocated survey effort relative to expected densities of KIMU using unequal probability sampling (Stevens and Olsen 2004). To avoid placing transects parallel to the observed density gradient of murrelets (Drew et al. 2008, Kirchhoff 2011) and to provide representative coverage across water depths, we oriented linear transects perpendicular to the local prevailing shoreline. In more enclosed waters we used shore-to-shore zigzag transects to avoid undesirably short transects. Transects are sampled according to an augmented, serially alternating panel design (McDonald 2003), where one permanent panel (set of transects) is sampled annually and three others are visited on a three-year rotation, with 2016 including the first-year panel (Figure 1).

See Chapter 2 and Appendix B of the long-term monitoring protocol for more detail (Hoekman et al. 2013).

Boat survey methods

We conducted boat-based line transect surveys (Buckland et al. 2001) at a speed of ≤10 km/h aboard the National Park Service R/V Fog Lark, an 8.5 m landing craft with a large front deck that provided a viewing height of approximately 3 m above the water line for two observers. For all groups (murrelets of one species class in a flock) initially located on the water, observers recorded group size, species class (KIMU, MAMU, or unidentified), and estimates of distance and angle in a straight line projecting forward from the bow of the boat. The allowable Beaufort sea state was ≤ 2. Program *Park Observer* (iOS-based software refined by R. Sarwas and W. Johnson, National Park Service) was used for the first time in 2016 and replaced the previous PC-based software, *NPTransect*, to record observations and associated GPS-based date/time/location stamps.

See the long-term monitoring protocol (Chapter 3 of the narrative, Standard Operating Procedures, hereafter “SOPs,” 1, 2, 3, and 9, and Appendix F) for more detail (Hoekman et al. 2013). At this time, the monitoring protocol has not been updated with operational details specific to *Park Observer*.

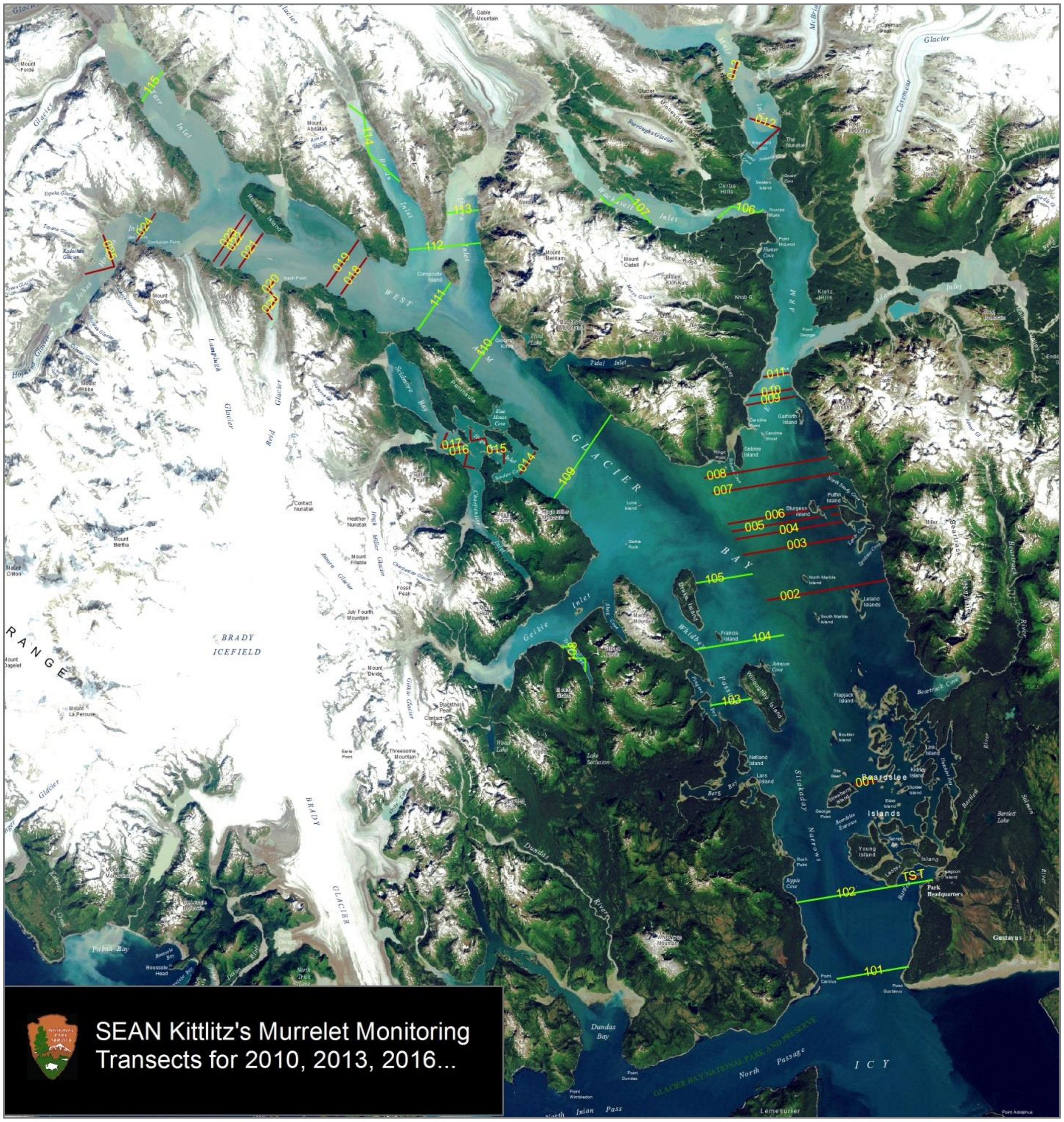

Figure 1. Line transects surveyed for murrelets in July 2016. Permanent (red lines) and Panel 1 (green) transects were surveyed as part of an augmented, serially alternating panel design with a three-year rotation. Linear transects were used in open waters (>2.5 km wide) and zigzag transects were used in more restricted waters. Transects extended from shore to shore, except a few truncated at mid-Bay to maintain optimal transect length. Linear transects were oriented perpendicular to the prevailing shoreline. The orientation of zigzag transects relative to shore was determined by the width of each area.

Abundance estimation

We estimated detection probability and group size using Program DISTANCE version 6.2 (Thomas et al. 2010) and species-specific abundance using statistical software R version 3.2.2 (R Core Team 2015) following recommended distance sampling methods (Buckland et al. 2001) and protocol SOP 12 (Hoekman et al. 2013). We modified distance sampling methods to account for incomplete detection near the transect center line and unidentified murrelets. Adjustments for unidentified murrelets assumed correct species identification and identical proportions of each species in the identified and unidentified samples. Density estimates were based on several component parameters: detection probability across the transect width, detection probability near the center line, group size for each species class, and encounter rates for each species class. We estimated abundance by multiplying total study area (1,170 km^2) by estimated densities.

See Hoekman et al. (2011c) and the monitoring protocol (Hoekman et al. 2013; Appendices A and D, SOPs 11 and 12) for more detail.

Results and Discussion

In light of the pending synthesis report of all existing monitoring data from 2009-2016, here we present results and discussion in a combined and abbreviated format relative to previous years.

We surveyed 40 transects totaling 209.4 km from 7-12 July 2016 and recorded 1,144 on-water groups. All permanent and first-year panel transects were surveyed, including transects 024 and 025 in Johns Hopkins Inlet, which in the past were sometimes inaccessible due to ice (Figure 1). We classified 142 (12%) groups as KIMU, 901 (79%) as MAMU, and 101 (9%) as unidentified. This low proportion of unidentified birds reflects efforts over the past several years to improve observer training and promote the importance of identifying individuals to species, especially at closer distances to the transect line. Detection probability was moderate (0.67; Table 1) within our selected 180 m right-truncation distance. Our estimated detection function declined moderately within 50 m of the transect center line and showed a uniform, rapid decay at intermediate and longer distances (Figure 2), resulting in an estimated 121 m effective strip half-width (ESW). Sea surface and weather conditions were very fair during survey days. Sixty percent of all observations were made during Beaufort sea state 0, 39% at 1, and 1% at 2. Fifty percent of the observations were recorded during dry conditions with less than 50% cloud cover, 43% were recorded during dry conditions with greater than 50% cloud cover, and only 7% were recorded during rain, mist, or fog.

Table 1. Component parameter values used to estimate on-water density and abundance of Kittlitz's and marbled murrelets in Glacier Bay for July 2016. Group sizes were estimated as single averages for each species class (see SOP 11 of protocol for more detail).

Parameter	Estimate	SE	*P*-value	Degrees of freedom
Detection across transect width	0.67	0.04	–	1112
Detection near transect center line [a]	0.94	0.03	–	66
Group size: Average				
Kittlitz's murrelet [b]	2.00	0.11	–	141
Marbled murrelet	2.56	0.07	–	870
Unidentified murrelet	2.36	0.19	–	85
Group size: Regression estimate				
Kittlitz's murrelet	2.04	0.09	0.83	140
Marbled murrelet [b]	2.41	0.05	0.007	869
Unidentified murrelet [b]	1.98	0.14	0.04	84
Encounter rate (groups/km)				
Kittlitz's murrelet	0.64	0.11	–	38
Marbled murrelet	4.54	0.88	–	38
Unidentified murrelet	0.47	0.05	–	38

[a] Estimate from Hoekman et al. 2011c.

[b] Estimate selected for estimation of density and abundance.

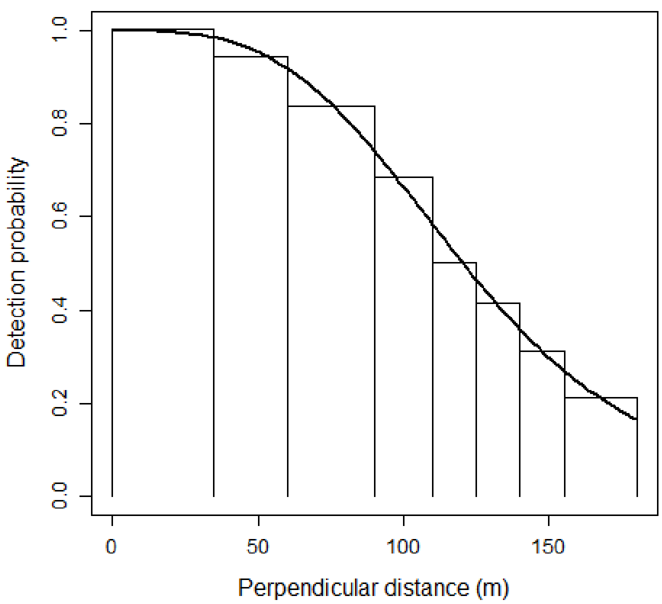

Figure 2. Estimated detection function for murrelets from line transect surveys in Glacier Bay, July 2016, illustrating estimated detection probability of murrelet groups relative to the perpendicular distances from the transect center line.

Higher group size and encounter rates for MAMU (Table 1) resulted in estimates of on-water density and abundance nearly nine times higher than KIMU (Table 2). The precision of our abundance estimates, measured as the coefficient of variation (CV; the estimated standard error divided by the estimated abundance) was nearly the same for KIMU (CV = 0.19) and MAMU (CV = 0.20). Since 2009, estimated density and precision have varied considerably for each species (Figure 3). Estimated KIMU abundance was the lowest since monitoring began in 2009 and decreased 35% from 2015, but it was very similar in magnitude to estimates from 2011 and 2013 (Table 2) and is not an obvious cause for concern. Estimated MAMU abundance was nearly the same as the 8-year monitoring average and decreased 28% from 2015. Abundance estimates since 2009 demonstrate that Glacier Bay's KIMU population continues to comprise an important fraction of the estimated minimum global population (USFWS 2013), but MAMU continue to be much more abundant in Glacier Bay.

Table 2. Estimates of on-water population density and abundance of Kittlitz's and marbled murrelets in Glacier Bay during July. Abundance was projected across surveyed waters only. Note that pilot surveys in 2009 differed in survey area (1,092 km^2) and methods (Hoekman et al. 2011a).

	Kittlitz's murrelet				Marbled murrelet			
Year	**Density[a]**	**SE**	**Abundance**	**SE**	**Density[a]**	**SE**	**Abundance**	**SE**
2016	6.0	1.1	7,025	1,345	51.8	10.3	60,624	12,018
2015	9.2	2.2	10,778	2,598	71.6	10.3	83,793	12,044
2014	8.9	1.3	10,422	1,522	35.4	3.4	41,474	3,998
2013	6.2	1.7	7,210	2,046	72.2	13.2	84,428	15,394
2012	14.1	2.2	16,469	2,581	44.9	4.5	52,560	5,216
2011	6.4	1.0	7,477	1,119	63.1	6.0	73,766	7,055
2010	11.4	1.2	13,308	1,357	52.7	4.6	61,717	5,372
2009	12.0	3.7	13,124[b]	4,062	26.5	3.7	28,978[b]	4,077
All	**9.3**	**–**	**10,726**	**–**	**52.3**	**–**	**60,917**	**–**

[a]Individuals/km^2

[b]Abundance extrapolated over 1,092 km^2 of sampled waters; all others extrapolated over 1,170 km^2.

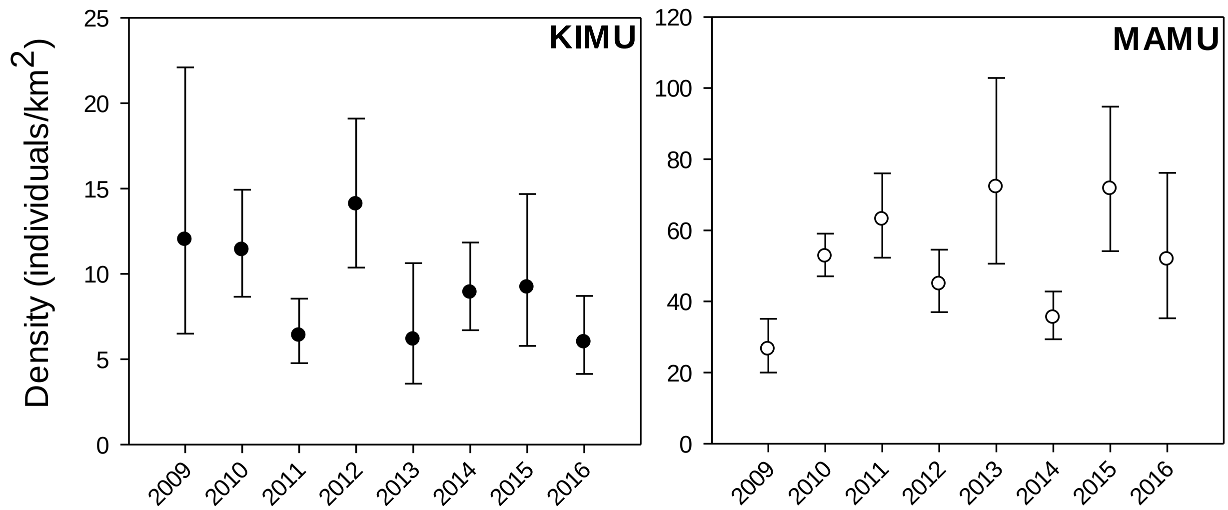

Figure 3. July densities (individuals/km^2) of Kittlitz's (KIMU, black circles) and marbled murrelets (MAMU, white circles) in Glacier Bay survey area from 2009-2016. Error bars are 95% confidence intervals. Note differing y-axis scales for density and that 2009 estimates were based on pilot survey methods (Hoekman 2011a). Densities are displayed to control for differences in survey area for 2009 (1,092 km^2) relative to 2010-2016 (1,170 km^2).

KIMU densities appeared to be patchier and more concentrated relative to previous years (Figure 4). High density areas for 2016 included the Marble Islands and most of the upper west arm, especially the mouths of Rendu and Queen Inlets, the west side of Russell Island, Reid Inlet, and mid-Tarr Inlet. Very few KIMU were encountered in the lower bay and the west side of mid-Glacier Bay. MAMU were present throughout the bay, but were especially dense in mid- and lower Glacier Bay regions (Figure 5). MAMU density decreased sharply along transects closest to fjord heads.

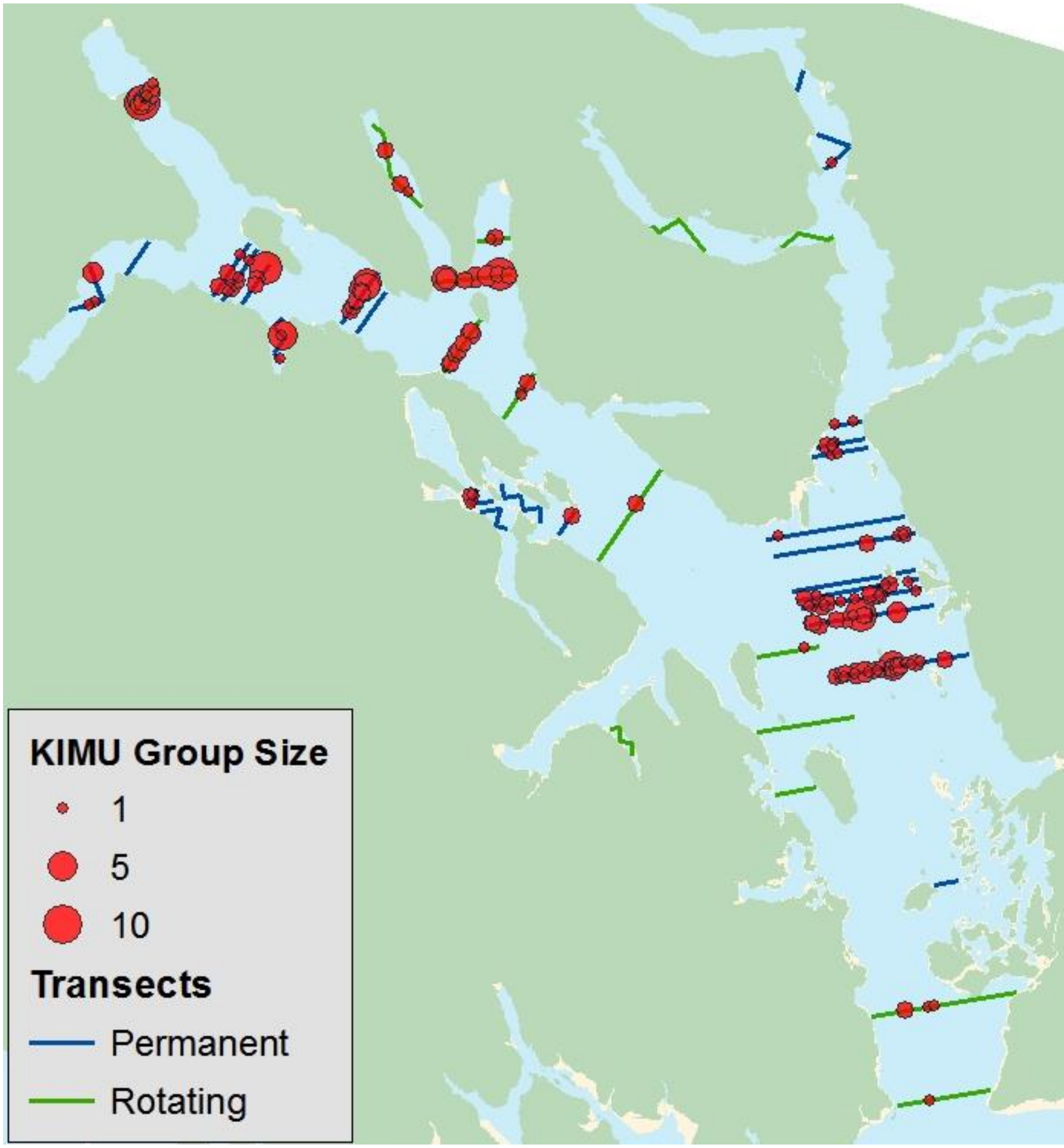

Figure 4. Spatial distribution of Kittlitz's murrelets observed during line transect surveys in Glacier Bay, July 2016. The area of circles is proportional to group size.

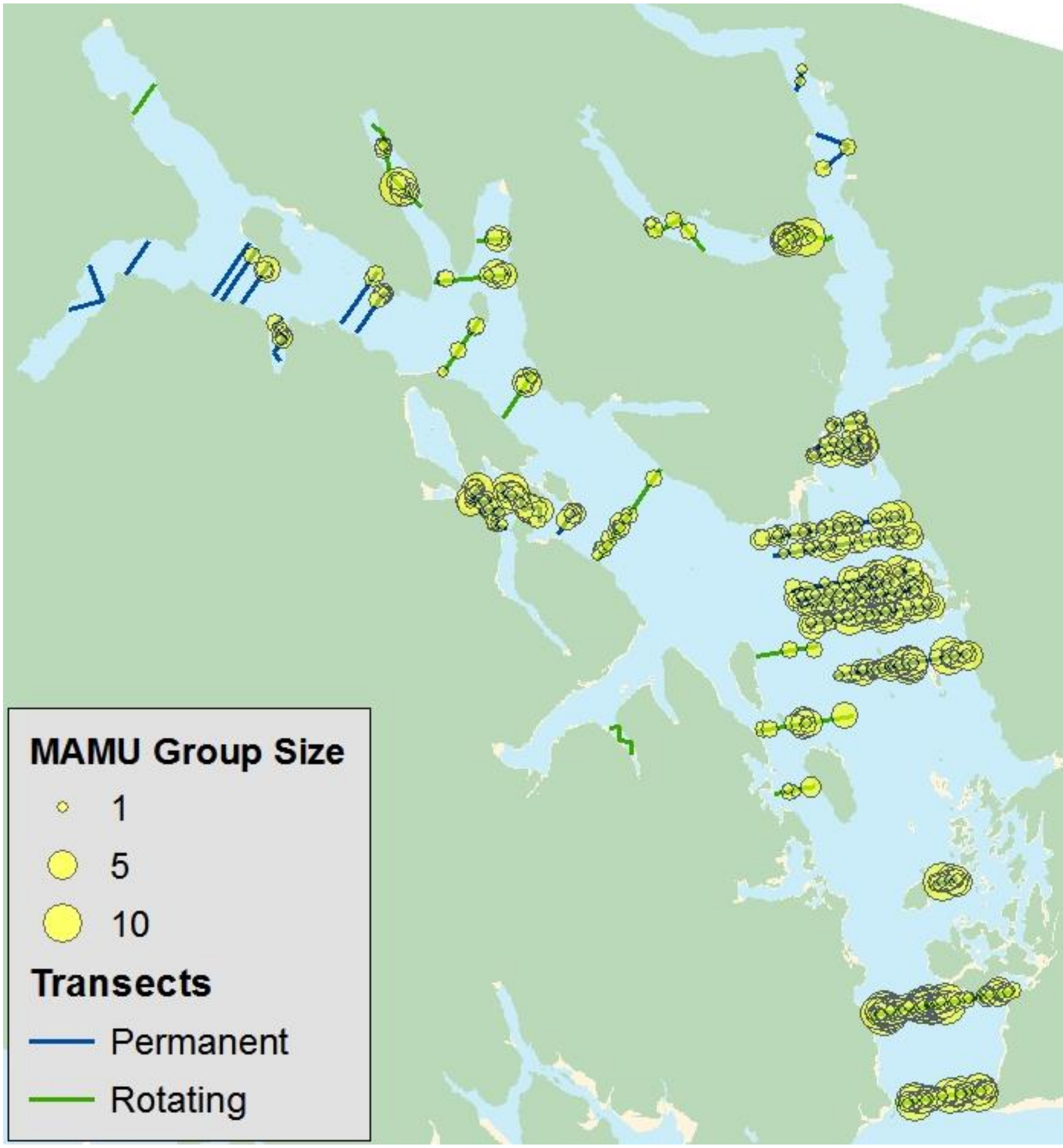

Figure 5. Spatial distribution of marbled murrelets observed during line transect surveys in Glacier Bay, July 2016. The area of circles is proportional to group size.

Recommendations

The SEAN and S. Hoekman (Wild Ginger Consulting) are currently drafting a synthesis report with five major objectives: 1) summarize important results for survey years 2010-2016 with a focus on abundance and spatial distributions of murrelet populations, 2) review and summarize recent scientific literature relevant to the monitoring protocol and management of murrelets in Glacier Bay, 3) assess if field operations have met performance objectives, 4) assess performance of key sampling and analytic methods, and 5) provide recommendations for monitoring protocol revisions to enhance capacity to meet monitoring objectives and for management of murrelets in GLBA.

Pending the findings of this synthesis report, our results and experience to date suggest that key operational components of our protocol are functioning as intended: equipment and personnel have been sufficient for timely completion of surveys; species identification rates have been adequate; procedures, hardware, and software for data collection have functioned well; detection probability has been sufficient and detection functions have been robust; and our methods for allocating survey effort have generally been successful in increasing sampling where KIMU density is high.

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1201 Oakridge Drive, Suite 150
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